Progress Reporting and Review
NASA Kennedy Space Center
Exploration Systems Analysis and Technology Assessment Project

Launch & Landing Effects Ground Operations "LLEGO" Model

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Contents

Purpose of this Briefing

- **Inform the KSC operations and development community on a capability for enhanced understanding of recurring space transportation system ground operations via data, modeling and analysis**

- **Obtain feedback toward making the capability as relevant as possible for KSC in support of the Constellation (Cx) program**

- **Present a Use Case**
  - Provide support as added insight internal to local KSC Cx Ground Operations Element (GOE) processes that provide such figures of merit up the chain

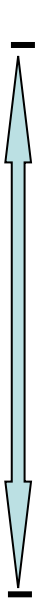
Context

"All research projects undertaken by the NACA sought to compile fundamental aeronautical knowledge applicable to all flight, rather than working on a specific type of aircraft design, because that looked too much like catering to a particular aeronautical firm."

The First Century of Flight: NACA/NASA Contributions to Aeronautics
http://teacherlink.ed.usu.edu/tlnasa/pictures/poster/FirstCenturyofFlight.pdf

Goal of this Project – Analysis
for Strategic Areas, Relationships, & Drivers

- **Use Case 1 "loading": Given, first, only Ground Operations contractor direct hands-on work content (derived elsewhere) for a specific flight hardware element (such as a CEV, a 2nd stage, etc), second, a launch demand, and third, a target time to fit that elements work into, output the rest of the KSC effects including the rest of the Ground Operations contractor, sub-contractors to the Ground Operations contractor, civil service, center management and operations and base infrastructure costs….by…**
  - 1a: Extrapolating past effects, assuming "business as usual" (BAU)
  - 1b: Extrapolating new effects, business with operational & supply chain improvements
- **Use Case 2 "root causes": Given / inputting the flight and ground system description by sub-systems, allow the model to calculate & adjust already co-related data, to calculate the value of Ground Operations contractor direct hands-on work content associated with each flight hardware element of the architecture…and…**
  - 2a: Use as is, no further analysis, to understand Ground Operations direct hands-on labor
  - 2b: Study what-if operability changes to the design affecting 2a
  - 2c: Use as a starting point for total cost via Use Case 1a or 1b



Simplest calculation and use case

Most complex calculation and use case

The Team & Acknowledgements

- **NASA Kennedy Space Center**
  - Edgar Zapata, Principal Investigator & COTR, KSC
  - Mike Galluzzi, Shuttle Program Office, Supply Chain Manager

- **Blue Frog Technologies Inc. TX**
  - Dr. Alex Ruiz-Torres, Lead Investigator and Integrator
  - Dr. Kazuo Nakatani, Systems Analyst

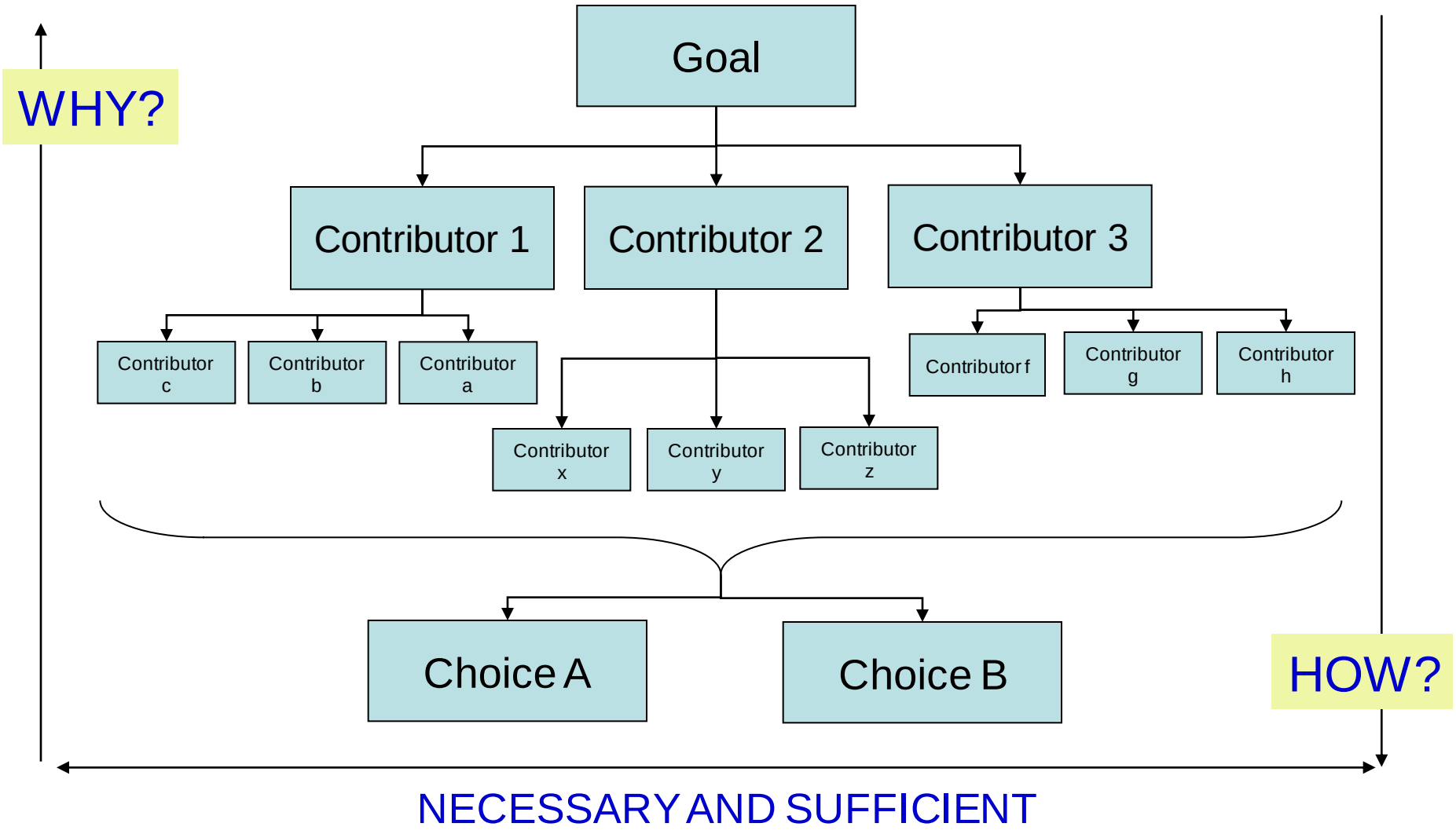
- **Acknowledgements: This project was funded by ESMD Level 1 as part of the ESR&T area**
  - Doug Craig, ESMD Directorate Integration Office (DIO)
  - Pat Troutman, LaRC and Bill Cirillo, LaRC leads Explorations Systems Analysis and Technology Assessment area “11B” from ESAS

Ground Operations Modeling, Background
Differences from Non-Recurring Type Parametric Estimation

- Ground Operations Modeling for Human Space Flight systems
  - Has not and is not evolving as a weight based nor parametric data driven science
    - Diverges significantly in method from NAFCOM type Spaceflight Hardware DDT&E and Production cost models
  - Supporting *data has emerged slowly; understanding and community agreement on use, applicability and significance still evolving
  - Not an area heavily invested in due to agency emphasis on near term budgets
    - New development takes years, leaving ops in the out-years
    - By the time ops is near-term, critical past decisions are irreversible

*Re. backup for data sources.

Ground Operations Modeling, Background
Hierarchy of Goals for Decision Making



Ground Operations Modeling, Background
Model Method & Influence Factors

- **Complexity:**
  - What is it? How much of it?
- **Reliability:**
  - Did it fail during a test? How confident am I that it won't fail when needed?
- **Operations & Supply Chain Management:**
  - What did we do with it?
  - What is the design of the organizations that support & operate it?
- ***Demand:**
  - How much of this does anyone want? At what price?

*Not addressed in this model, requires economic modeling

Ground Operations Modeling, Background
Model Method & Influence Factors

- **Definitions: Influence factors treed from root causes**

  - **Complexity**
    - **Factors: Number of stages, number of sub-systems, types of fluids, mission requirements such as number of flights, number of in-space operations, a technology choice that is more or less operable, a design more or less accessible.**
      - **Re. also Maintainability, Availability.**
  - **Reliability**
    - **Factors: The reliability, the margin, the design life – ultimately the quality of our product and the customer confidence in the product. Is loss of vehicle 1 in 100 or 1 in 1000? Affected heavily by quality.**
      - **Re. also Dependability, Variance, Confidence, Availability, Reusability.**
  - **Operation & Supply Chain Management**
    - **Factors: Processing the system. Is this a lean organization, with few process steps? A modern Supply Chain and modern systems? Or a set of manual, duplicative and labor intensive processes? American Airlines at 10 cents a passenger mile…or a low-cost airline at 7 cents a passenger mile? (Both get you there, identical technology, one goes bankrupt).**
      - **Re. Business processes (organizational), information technology (I/T) systems (examples: work control, logistics) and operational processes (example: horizontal vs. vertical processing).**
  - ***Demand & Economics**
    - **Factors: Variance increases as production rate decreases, inevitably being a driver in low volume production, assembly or services, by limiting the dependability, quality or learning possible or targeted in the operation.**
      - **Re. Uneconomical order quantities, reliability, confidence, monopoly behaviors, captive markets**

*Not addressed in this model, requires economic modeling

Ground Operations Modeling, Background

Scope: Recurring Ground Operations

The Current Human Space Flight Launch & Landing Operational Supply Chain




Prime Contractor Direct Touch Labor Element or Stack Level at KSC



Each hour of technician labor (or each "hand's on" person) in order to perform the work, requires...

Prime Contractor Engineering & Management, Safety & Quality, Direct Support at KSC

Prime Contractor All Other In-Direct Functions and Support at KSC

Prime Contractor Logistics and Depot Maintenance (Orbiter Only, NASA Shuttle Logistics Depot, NSLD, Cape Canaveral)

KSC Infrastructure

Other non-Prime Support, as Sub-Contracts to the Prime Contractor at KSC

Production, Hardware, & Program Level Functions

Lockheed-Martin (ETs) Lousiana, ATK (SRMs) Utah, Boeing Rocketdyne (SSMEs) California, USA (Prime) Texas JSC, NASA JSC Mission & Flight Ops Texas, NASA MSFC ET/SRM/SRB, SSME Program/Management Alabama, NASA HQ Program management Washington D.C.

=2.9 X the sum of all of all shown

...~82

NASA KSC Civil Servants, Engineering & Technical Management

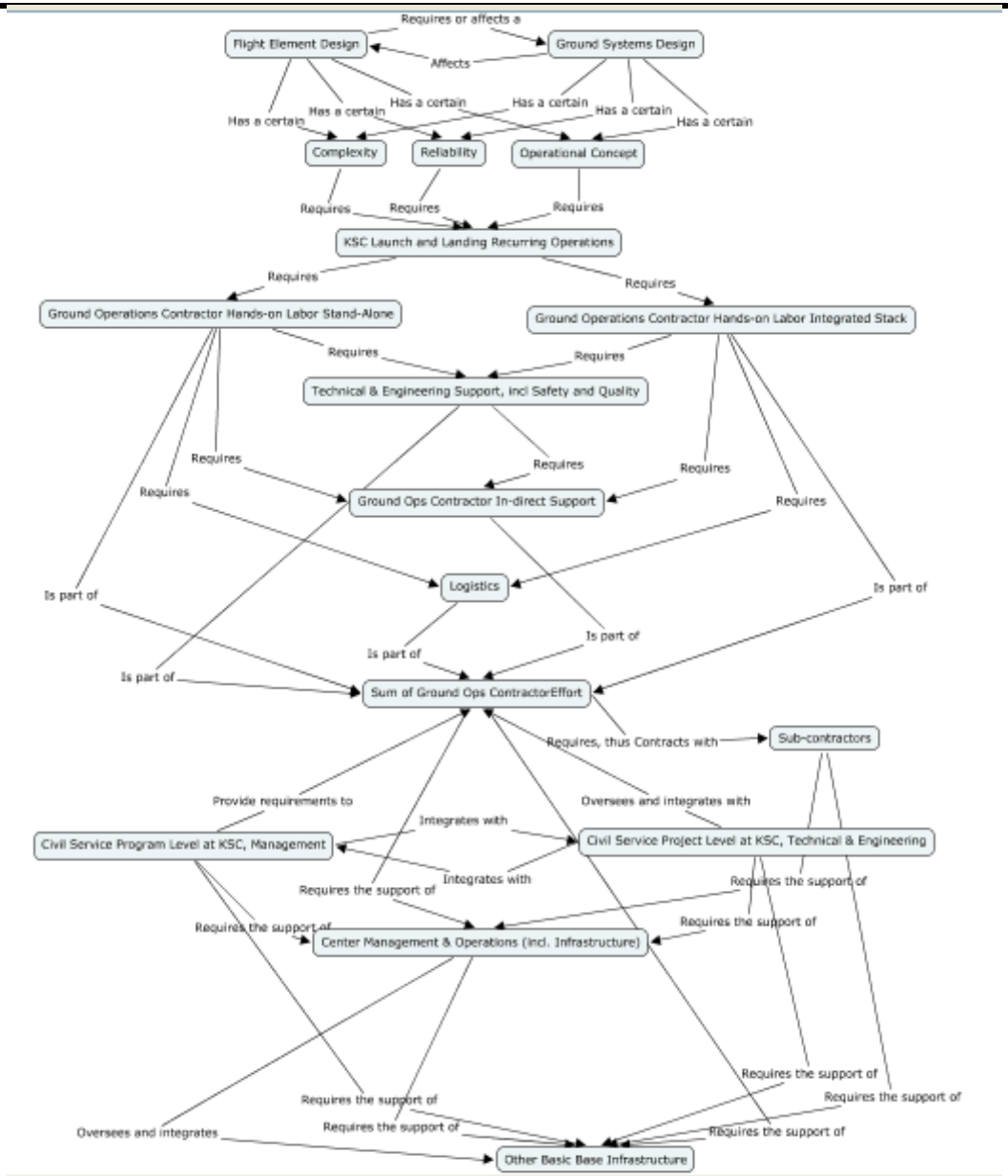
Enabling KSC NASA & Contractor Center Functions (Center Management and Operations, CMO)

ARF SRB Operations at KSC under MSFC Management

E.Zapata 1-25-07

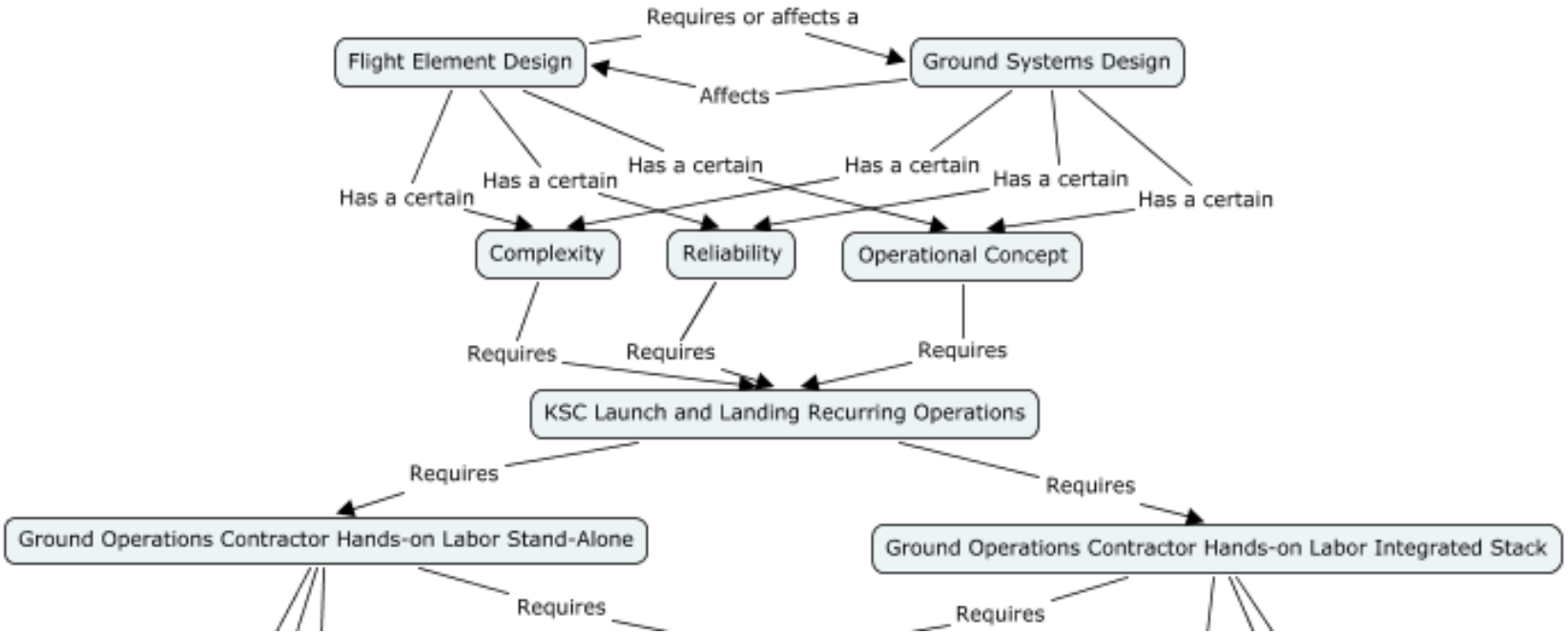
Methodology & General Structure of the Model

Concept Map



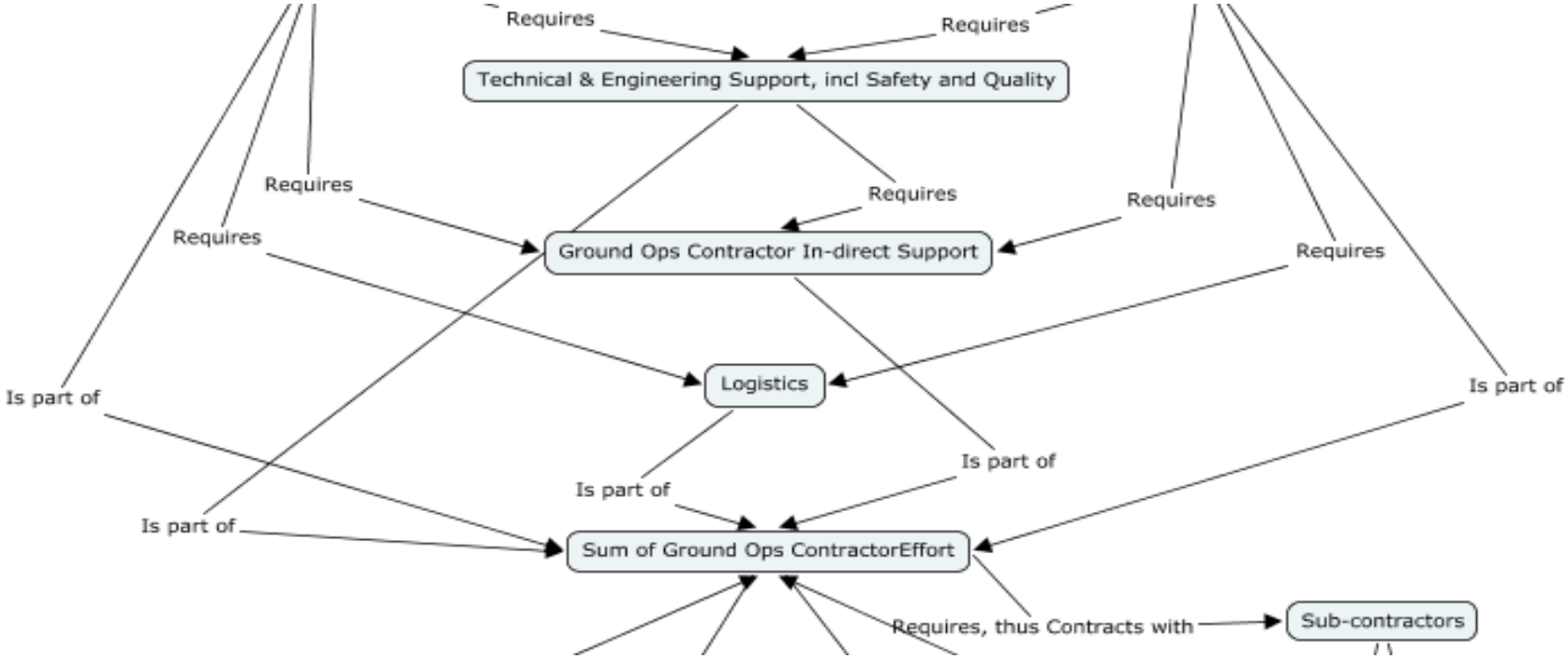
Methodology & General Structure of the Model

Concept Map 1 of 3



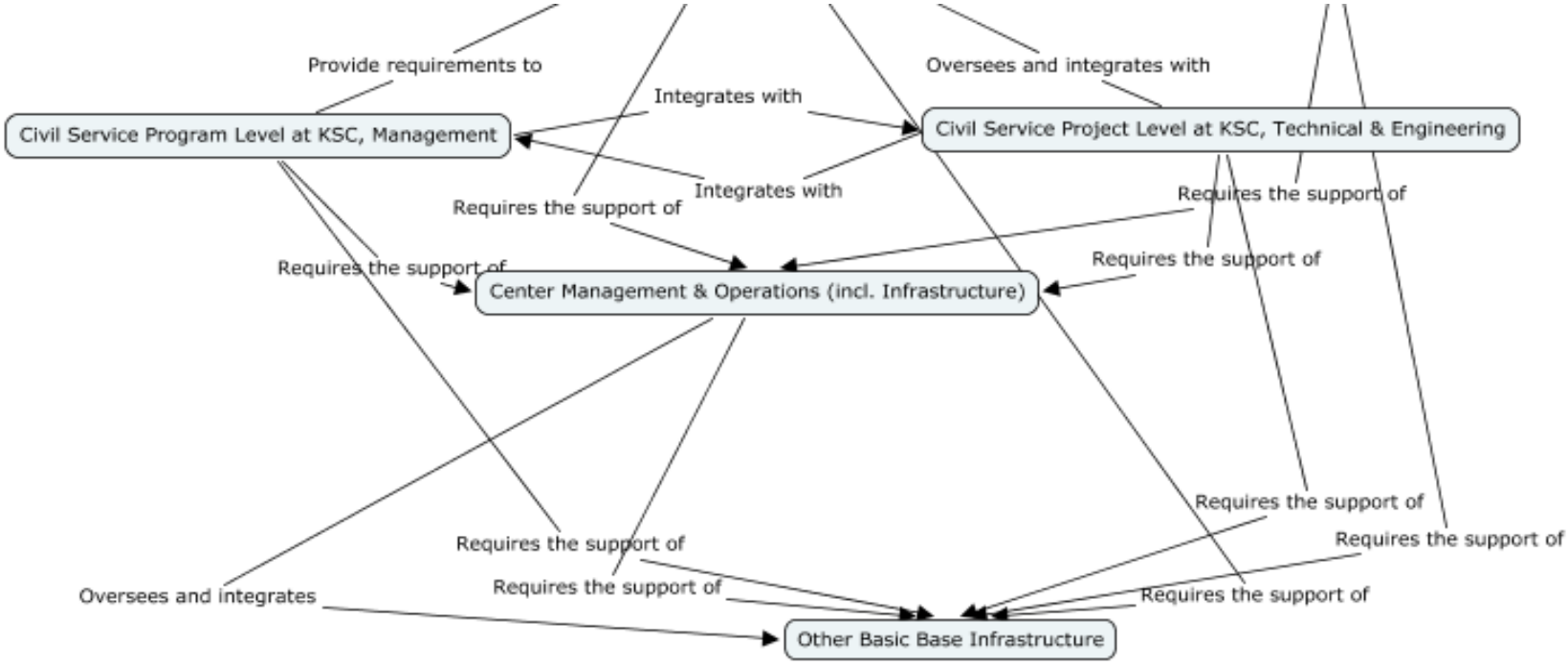
Methodology & General Structure of the Model

Concept Map 2 of 3



Methodology & General Structure of the Model

Concept Map 3 of 3



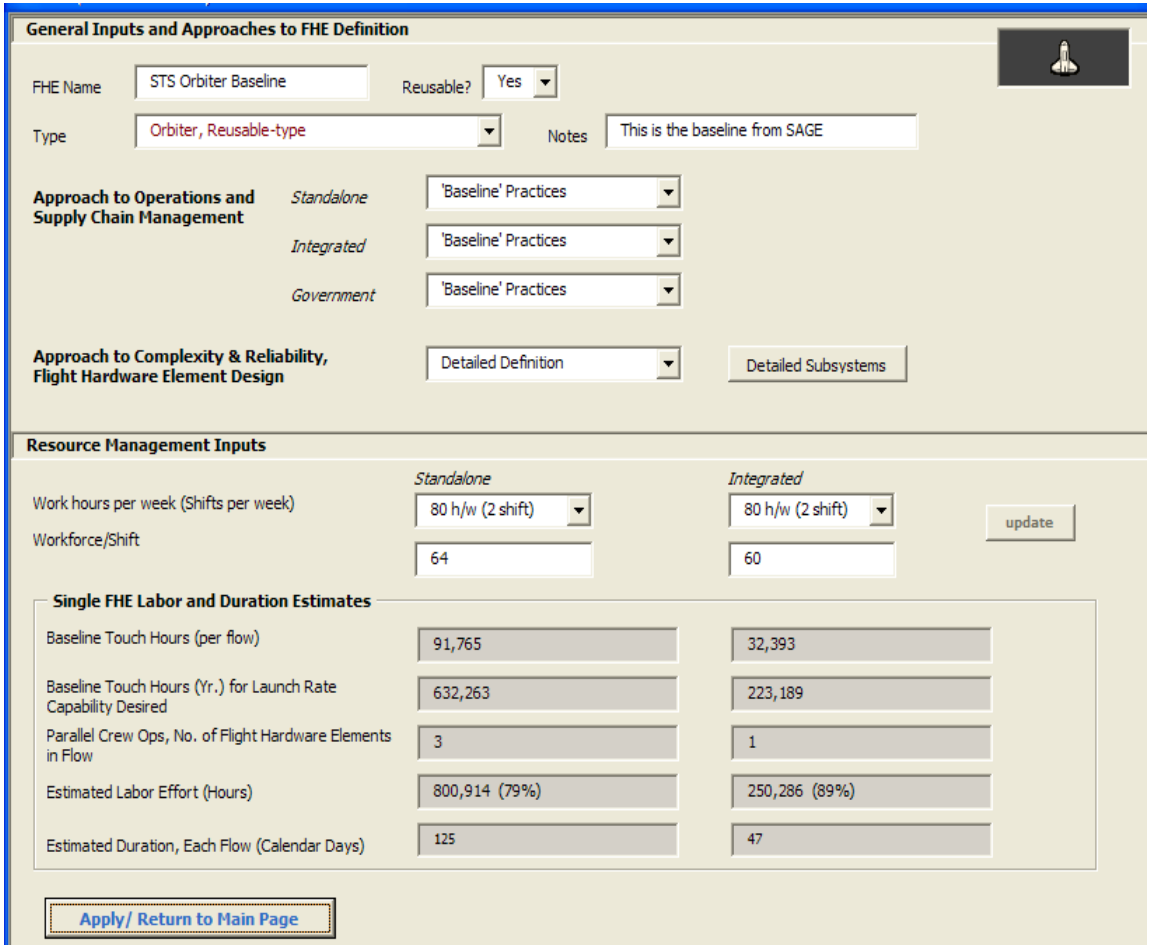
Methodology & General Structure of the Model
Labor-hours Relationship to Time & Productivity

Given, or calculated previously using the tool, an amount of effort, in units of labor-hrs:

AND

1) Entering shifts
2) Entering workforce / shift
3) A target launches / year

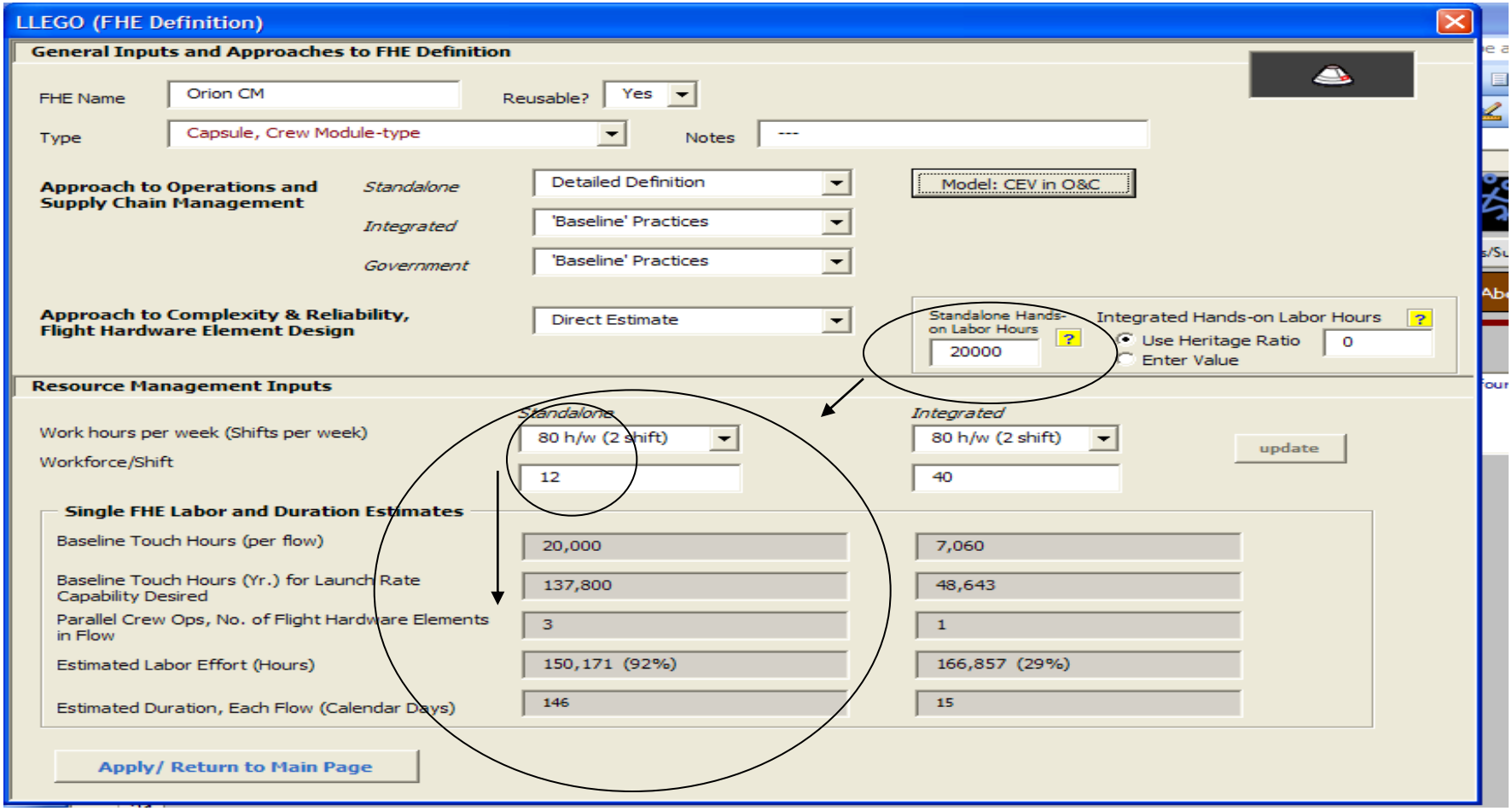
Then, output is the actual hours that will be expensed, and the time to accomplish that process (standalone or integrated), as well as the numbers of crews that are *consistent* with these inputs & outputs.



- *The user explores the final operational workforce with a logic similar to that a contractor may employ*
- *Current STS workforce realistically calculates this way.*

Software-LLEGO-Launch & Landing Effects Ground Ops Model
Simplest Use Case

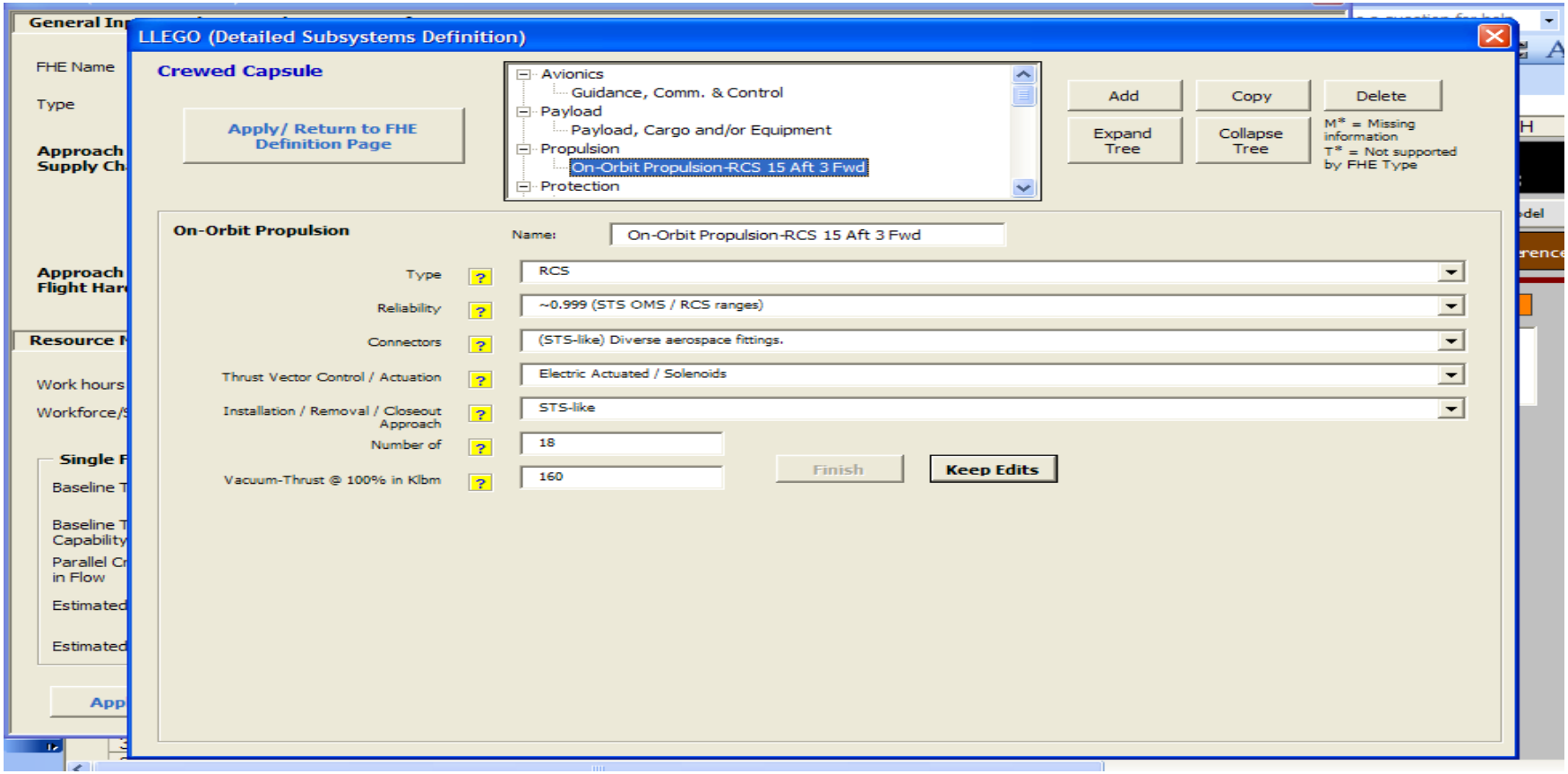
Simplest use case – entering hands-on effort, calculate for the user the rest of the KSC picture, assuming business as usual relationships.



Software-LLEGO-Launch & Landing Effects Ground Ops Model

Most Complex Use Case

Most complex use case: Characterizing & inputting flight hardware elements, AND choosing business & supply chain practices that are other than business as usual, & constraining fixed resources to a target (i.e. single string, etc) calculate the hands-on effort, and all other support and in-direct costs, outputting the total launch and landing cost.



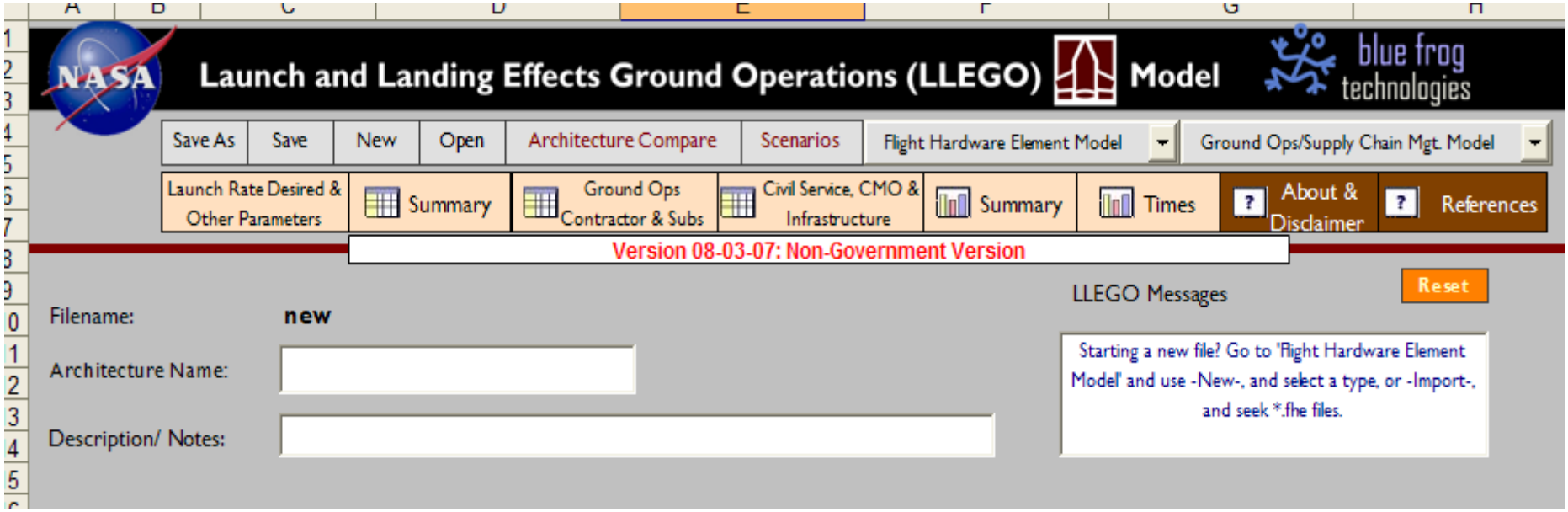
Demo (steps shown)

- **References**
- **Open**
- **STS - Summary- Perspective is all KSC Space transportation, munus ARF, but that is up ahead**
- **Other reports > go thru all…these are specific parts of the summary**
- **Last report "times"? Why time emphasis?**
- **i.e. Back to "Main"**
- **To Orbiter, 125 days vs. 80 days, cleaned up data vs. reality (issue), average vs. real variance (issue)**
- **Close**
- **Open Orion Ares I direct calc r5 6LPY – emphasis on caveats – evolving**
  - Definitions between all KSC vs. just GOE will soon have dedicated reports…not include CMO, base infrastructure
- **On that note…over to "Architecture Compare"**
  - Load prior plus STS
- **On that note…over to "Main" – "Open" "Orion Ares I direct calc r5a GOEs4" – Emphasize, just a scenario**
- **Over to "Main" – blank – FHE features…import CapsuleB.fhe**
- **Over to "Orion Ares I direct calc r5 6 LPY"… "Summary"**
- **Import "CEV in O&C" practices-emphasize, still in sensitivity study phase, soon to be some analysis coming forth…Show change in results…**
- **All this has been "direct calculation"…simple use cases, Back to STS…Open…Detailed Definition…more complex use cases**
- **Over to "Scenario Analyzer"**
- **Over to "Slider"**
- **Emphasize…more reports evolving…benefit of Excel structure**
- **Back to charts**

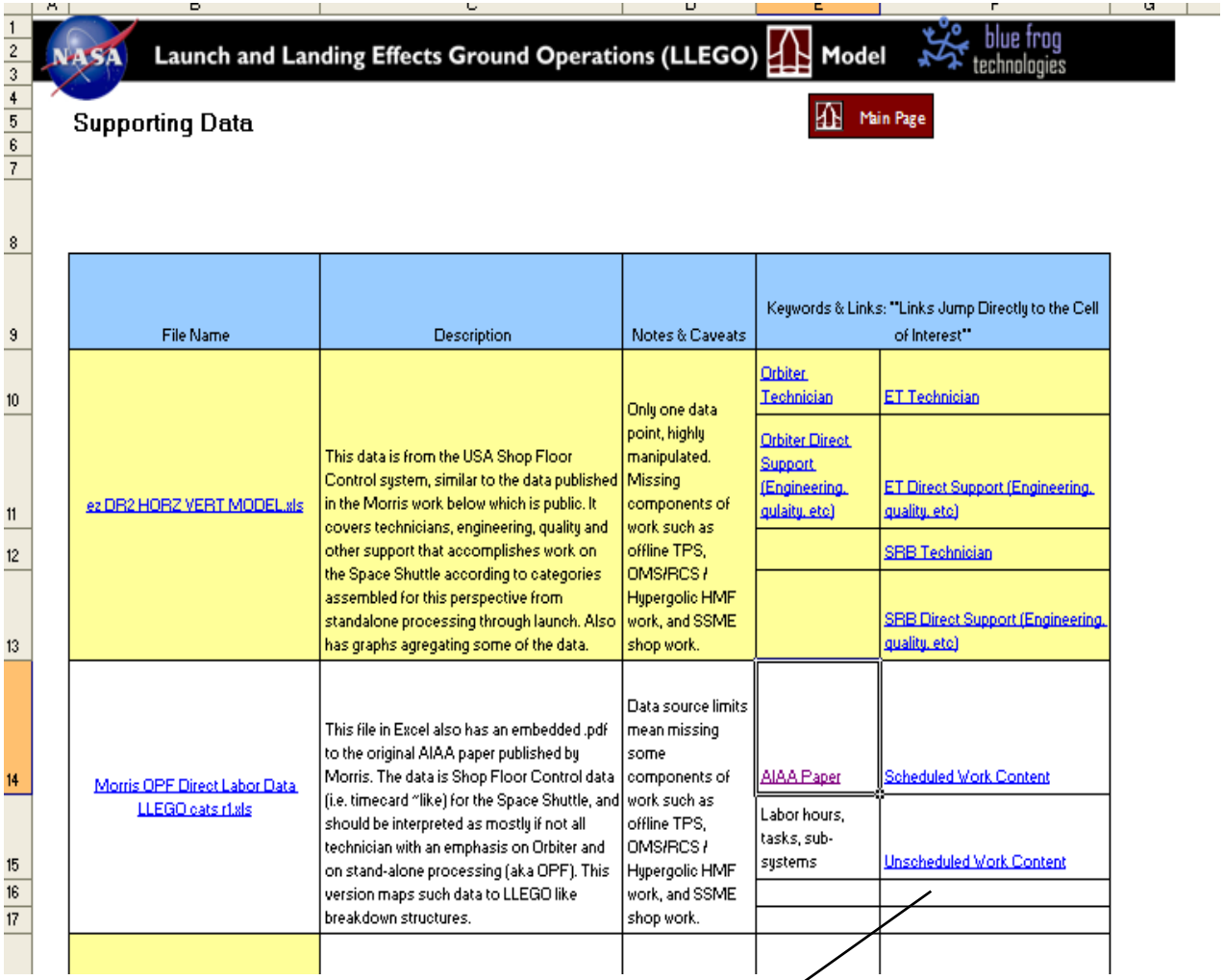
Demo (Webex) or Screen-shots

Skip Screen Shots

Demo-Starting Point



Demo-Click Button "References"



Launch and Landing Effects Ground Operations (LLEGO) Model

blue frog technologies

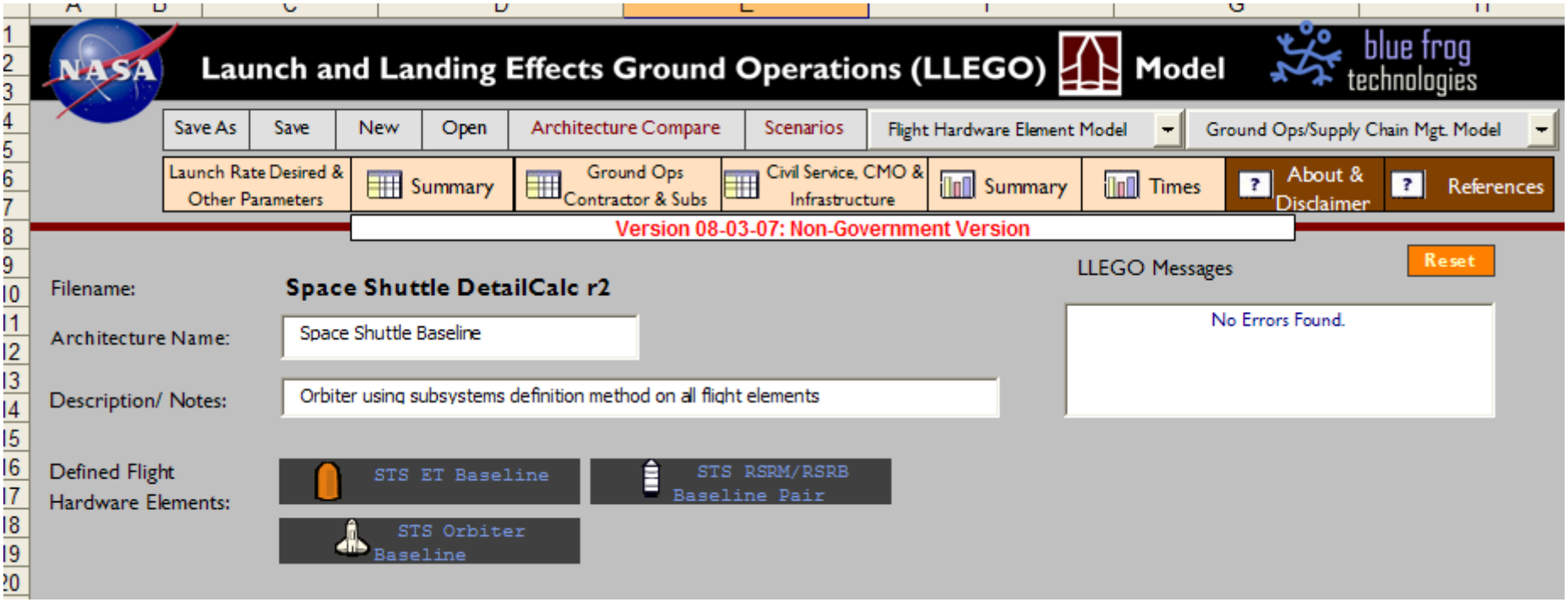
Main Page

Supporting Data

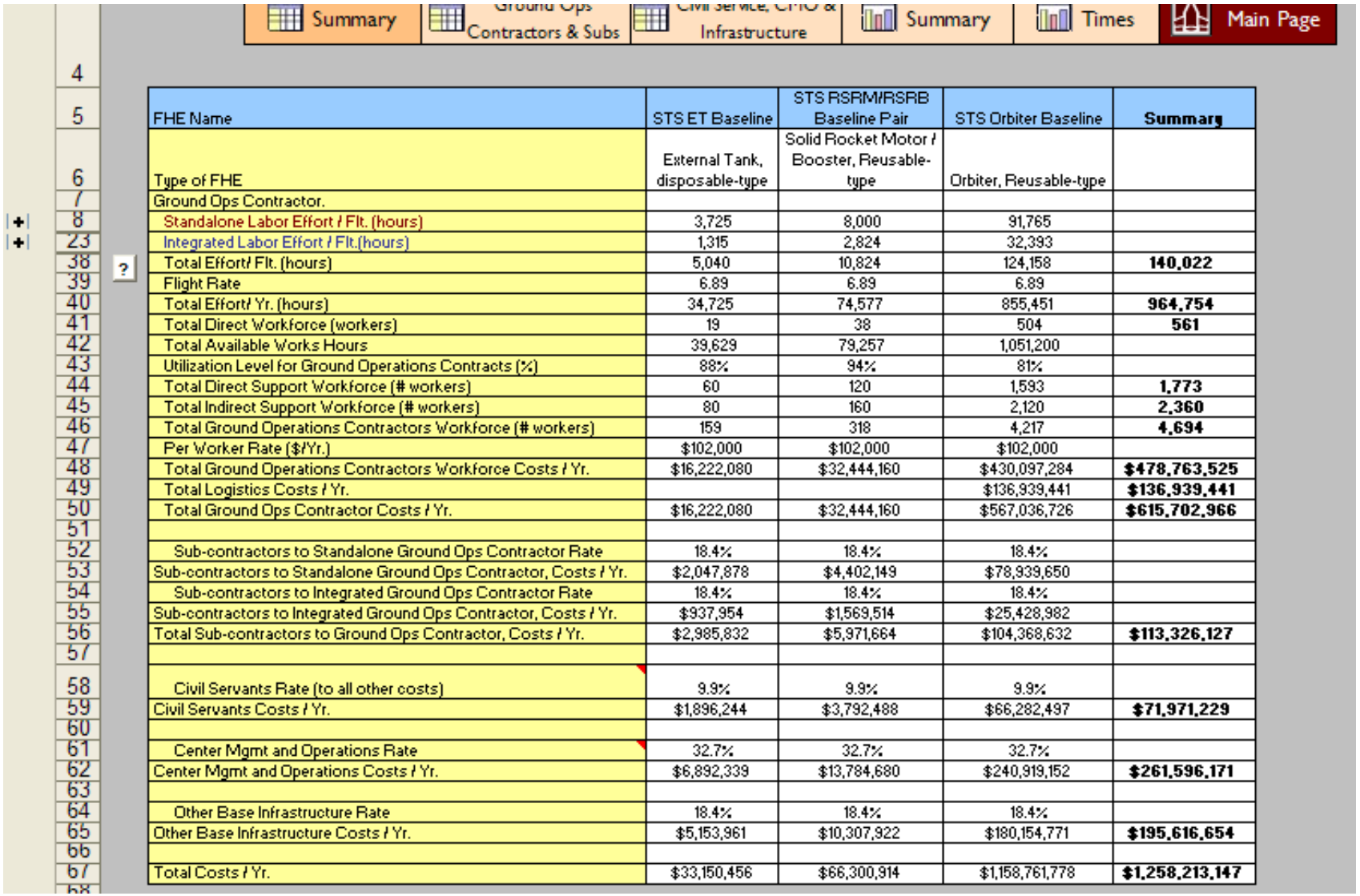
File Name	Description	Notes & Caveats	Keywords & Links: "Links Jump Directly to the Cell of Interest"	
ez DR2 HORZ VERT MODEL.xls	This data is from the USA Shop Floor Control system, similar to the data published in the Morris work below which is public. It covers technicians, engineering, quality and other support that accomplishes work on the Space Shuttle according to categories assembled for this perspective from standalone processing through launch. Also has graphs agregating some of the data.	Only one data point, highly manipulated. Missing components of work such as offline TPS, OMS/RCS / Hypergolic HMF work, and SSME shop work.	Orbiter Technician	ET Technician
			Orbiter Direct Support (Engineering, qulaity, etc)	ET Direct Support (Engineering, quality, etc)
				SRB Technician
				SRB Direct Support (Engineering, quality, etc)
Morris OPF Direct Labor Data LLEGO cats r1.xls	This file in Excel also has an embedded .pdf to the original AIAA paper published by Morris. The data is Shop Floor Control data (i.e. timecard "like) for the Space Shuttle, and should be interpreted as mostly if not all technician with an emphasis on Orbiter and on stand-alone processing (aka OPF). This version maps such data to LLEGO like breakdown structures.	Data source limits mean missing some components of work such as offline TPS, OMS/RCS / Hypergolic HMF work, and SSME shop work.	AIAA Paper	Scheduled Work Content
			Labor hours, tasks, sub-systems	Unscheduled Work Content

Links to source data, more .xls, jpg. etc

Demo- “Open” “Space Shuttle DetailCalc r2.far”



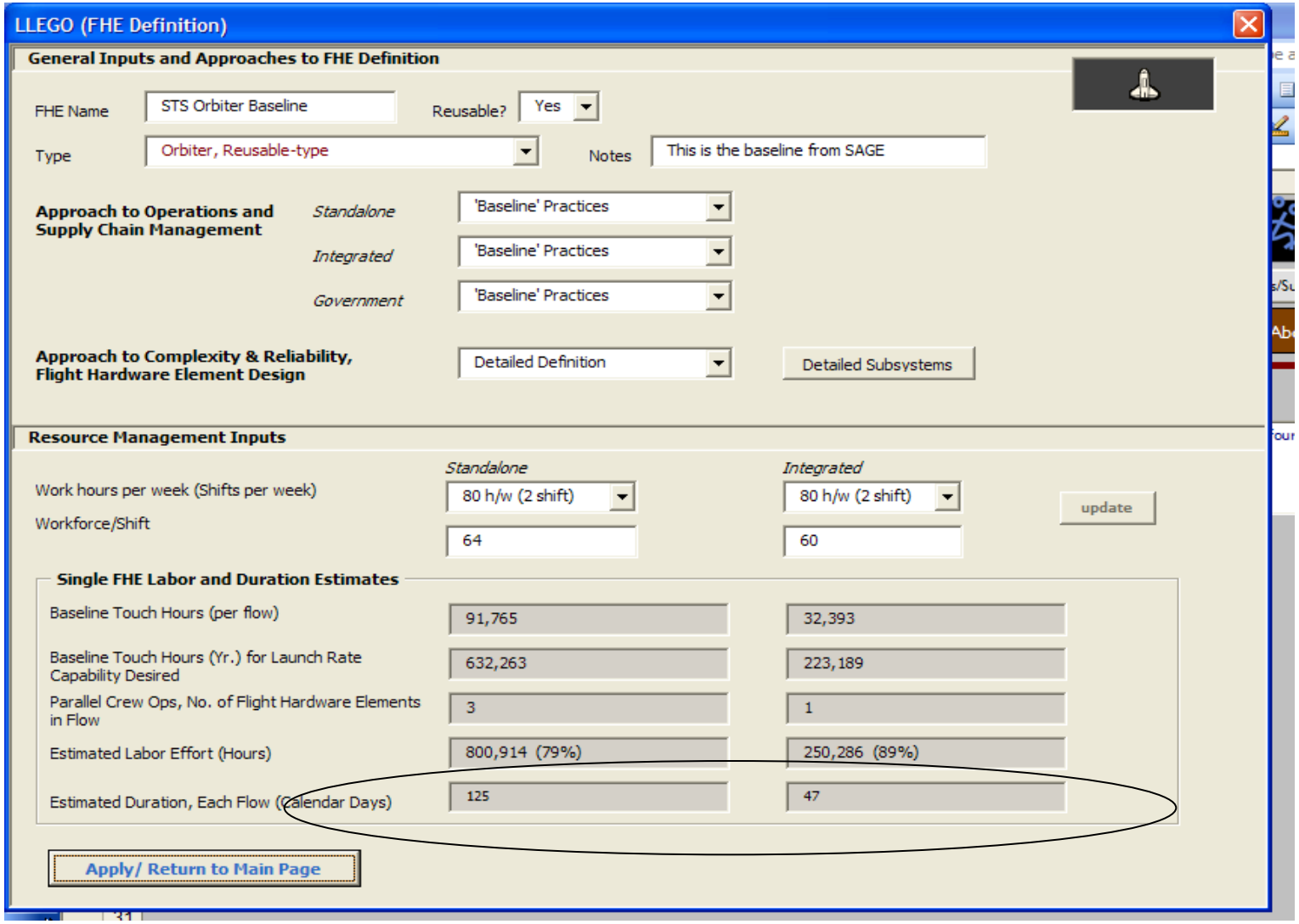
Demo- “Summary” report (STS loaded)



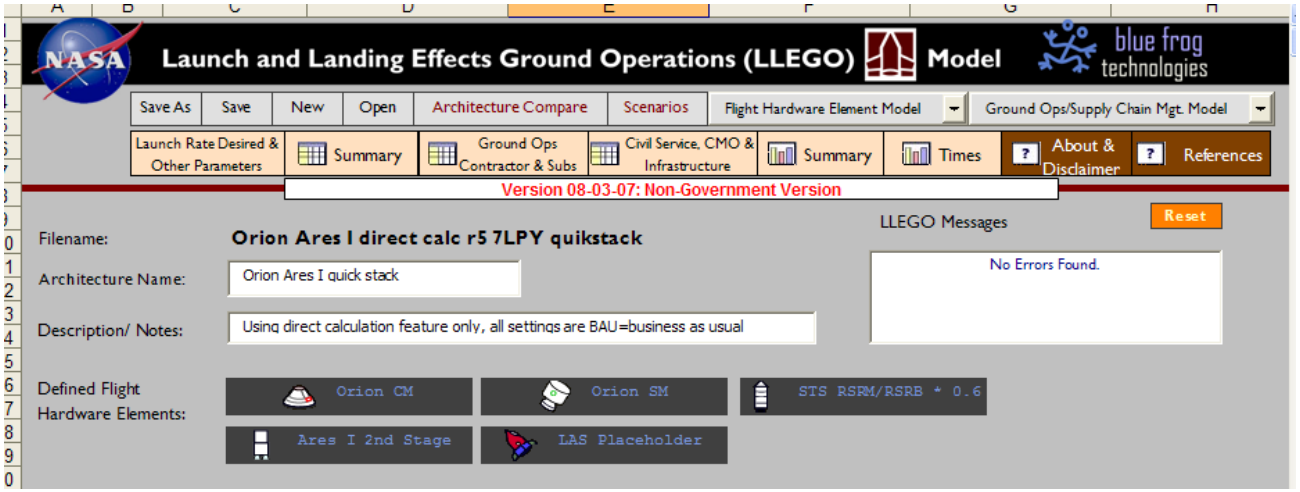
Summary | Ground Ops Contractors & Subs | Civil Service, CHO & Infrastructure | Summary | Times | Main Page

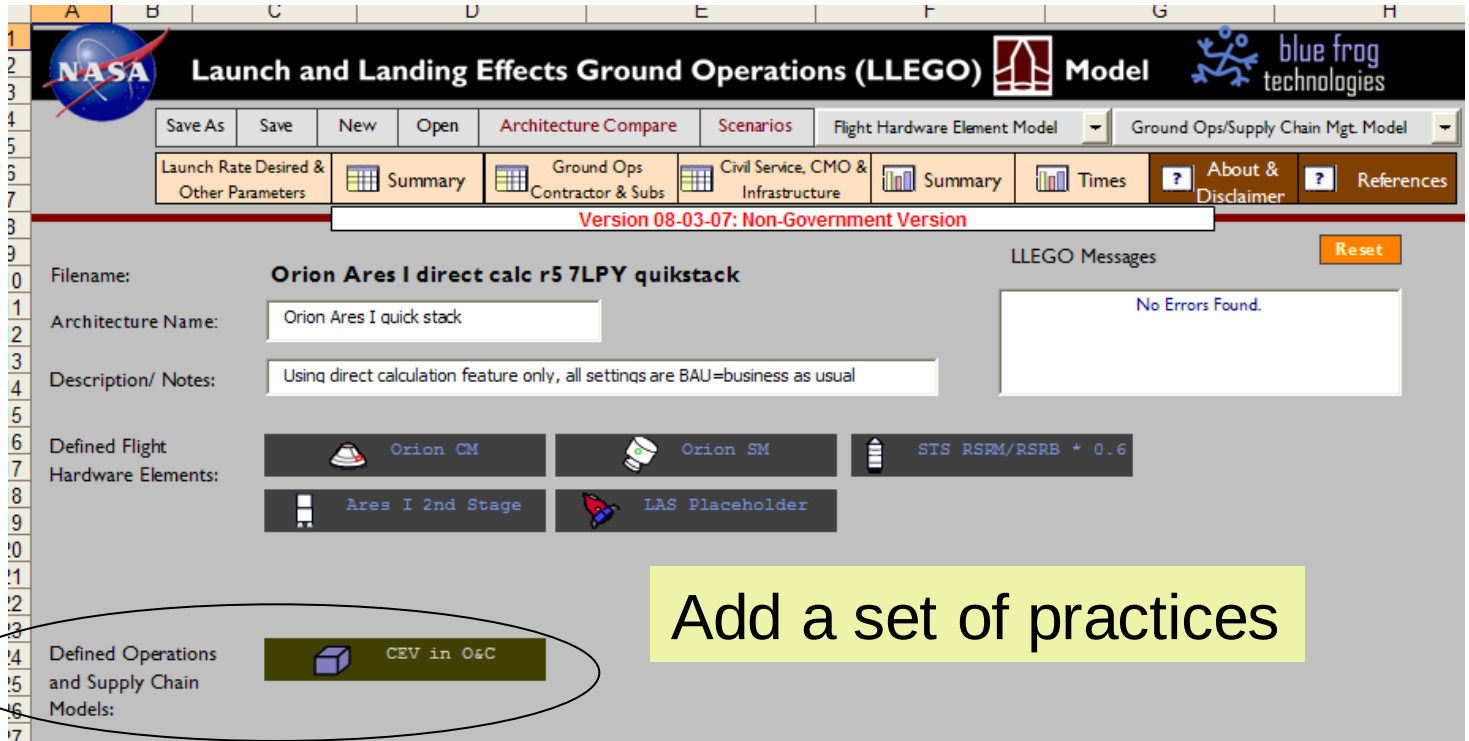
FHE Name	STS ET Baseline	STS RSRM/RSRB Baseline Pair	STS Orbiter Baseline	Summary
Type of FHE	External Tank, disposable-type	Solid Rocket Motor / Booster, Reusable-type	Orbiter, Reusable-type	
Ground Ops Contractor.				
Standalone Labor Effort / Flt. (hours)	3,725	8,000	91,765	
Integrated Labor Effort / Flt.(hours)	1,315	2,824	32,393	
Total Effort/ Flt. (hours)	5,040	10,824	124,158	**140,022**
Flight Rate	6.89	6.89	6.89	
Total Effort/ Yr. (hours)	34,725	74,577	855,451	**964,754**
Total Direct Workforce (workers)	19	38	504	**561**
Total Available Works Hours	39,629	79,257	1,051,200	
Utilization Level for Ground Operations Contracts (%)	88%	94%	81%	
Total Direct Support Workforce (# workers)	60	120	1,593	**1,773**
Total Indirect Support Workforce (# workers)	80	160	2,120	**2,360**
Total Ground Operations Contractors Workforce (# workers)	159	318	4,217	**4,694**
Per Worker Rate ($/Yr.)	$102,000	$102,000	$102,000	
Total Ground Operations Contractors Workforce Costs / Yr.	$16,222,080	$32,444,160	$430,097,284	**$478,763,525**
Total Logistics Costs / Yr.			$136,939,441	**$136,939,441**
Total Ground Ops Contractor Costs / Yr.	$16,222,080	$32,444,160	$567,036,726	**$615,702,966**
Sub-contractors to Standalone Ground Ops Contractor Rate	18.4%	18.4%	18.4%	
Sub-contractors to Standalone Ground Ops Contractor, Costs / Yr.	$2,047,878	$4,402,149	$78,939,650	
Sub-contractors to Integrated Ground Ops Contractor Rate	18.4%	18.4%	18.4%	
Sub-contractors to Integrated Ground Ops Contractor, Costs / Yr.	$937,954	$1,569,514	$25,428,982	
Total Sub-contractors to Ground Ops Contractor, Costs / Yr.	$2,985,832	$5,971,664	$104,368,632	**$113,326,127**
Civil Servants Rate (to all other costs)	9.9%	9.9%	9.9%	
Civil Servants Costs / Yr.	$1,896,244	$3,792,488	$66,282,497	**$71,971,229**
Center Mgmt and Operations Rate	32.7%	32.7%	32.7%	
Center Mgmt and Operations Costs / Yr.	$6,892,339	$13,784,680	$240,919,152	**$261,596,171**
Other Base Infrastructure Rate	18.4%	18.4%	18.4%	
Other Base Infrastructure Costs / Yr.	$5,153,961	$10,307,922	$180,154,771	**$195,616,654**
Total Costs / Yr.	$33,150,456	$66,300,914	$1,158,761,778	**$1,258,213,147**

Demo-Times…


LLEGO (FHE Definition)
General Inputs and Approaches to FHE Definition
FHE Name
STS Orbiter Baseline
Reusable?
Yes
Type
Orbiter, Reusable-type
Notes
This is the baseline from SAGE
Approach to Operations and Supply Chain Management
Standalone
'Baseline' Practices
Integrated
'Baseline' Practices
Government
'Baseline' Practices
Approach to Complexity & Reliability, Flight Hardware Element Design
Detailed Definition
Detailed Subsystems
Resource Management Inputs
Standalone
Integrated
Work hours per week (Shifts per week)
80 h/w (2 shift)
80 h/w (2 shift)
update
Workforce/Shift
64
60
Single FHE Labor and Duration Estimates
Baseline Touch Hours (per flow)
91,765
32,393
Baseline Touch Hours (Yr.) for Launch Rate Capability Desired
632,263
223,189
Parallel Crew Ops, No. of Flight Hardware Elements in Flow
3
1
Estimated Labor Effort (Hours)
800,914 (79%)
250,286 (89%)
Estimated Duration, Each Flow (Calendar Days)
125
47
Apply/ Return to Main Page

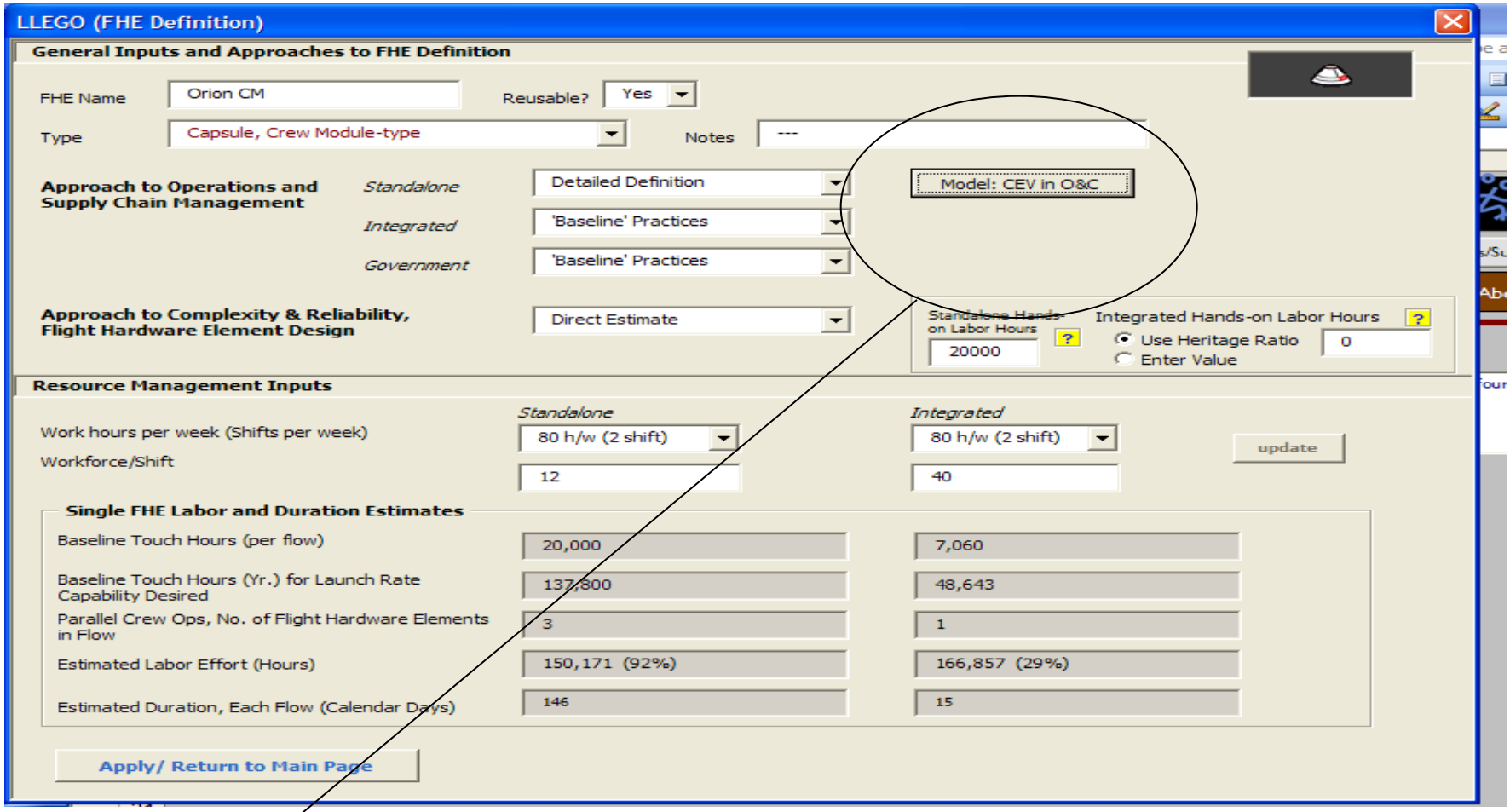
Demo-Effect of Changes to Business as Usual





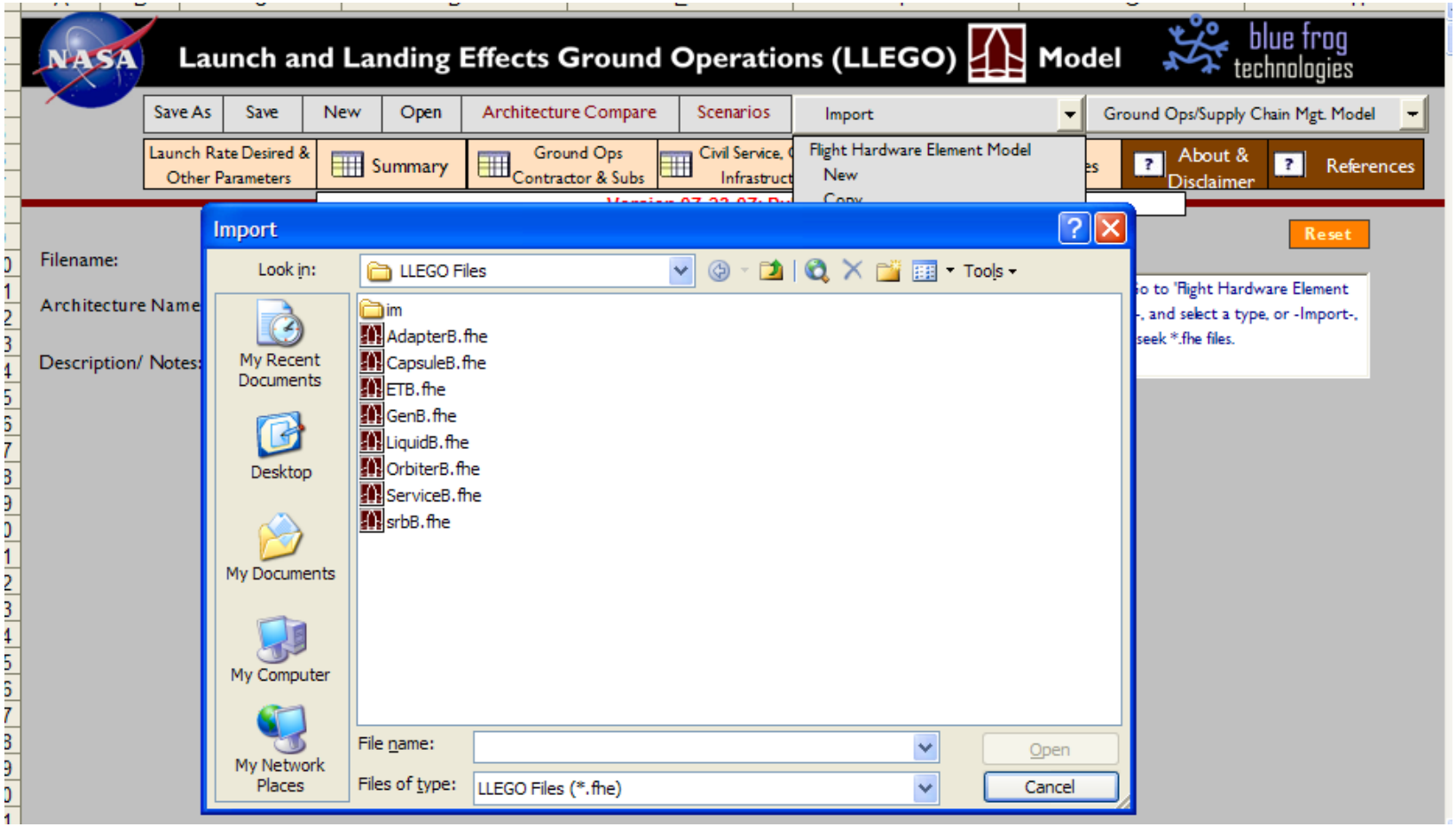
Add a set of practices

Demo-Effect of Changes to Business as Usual



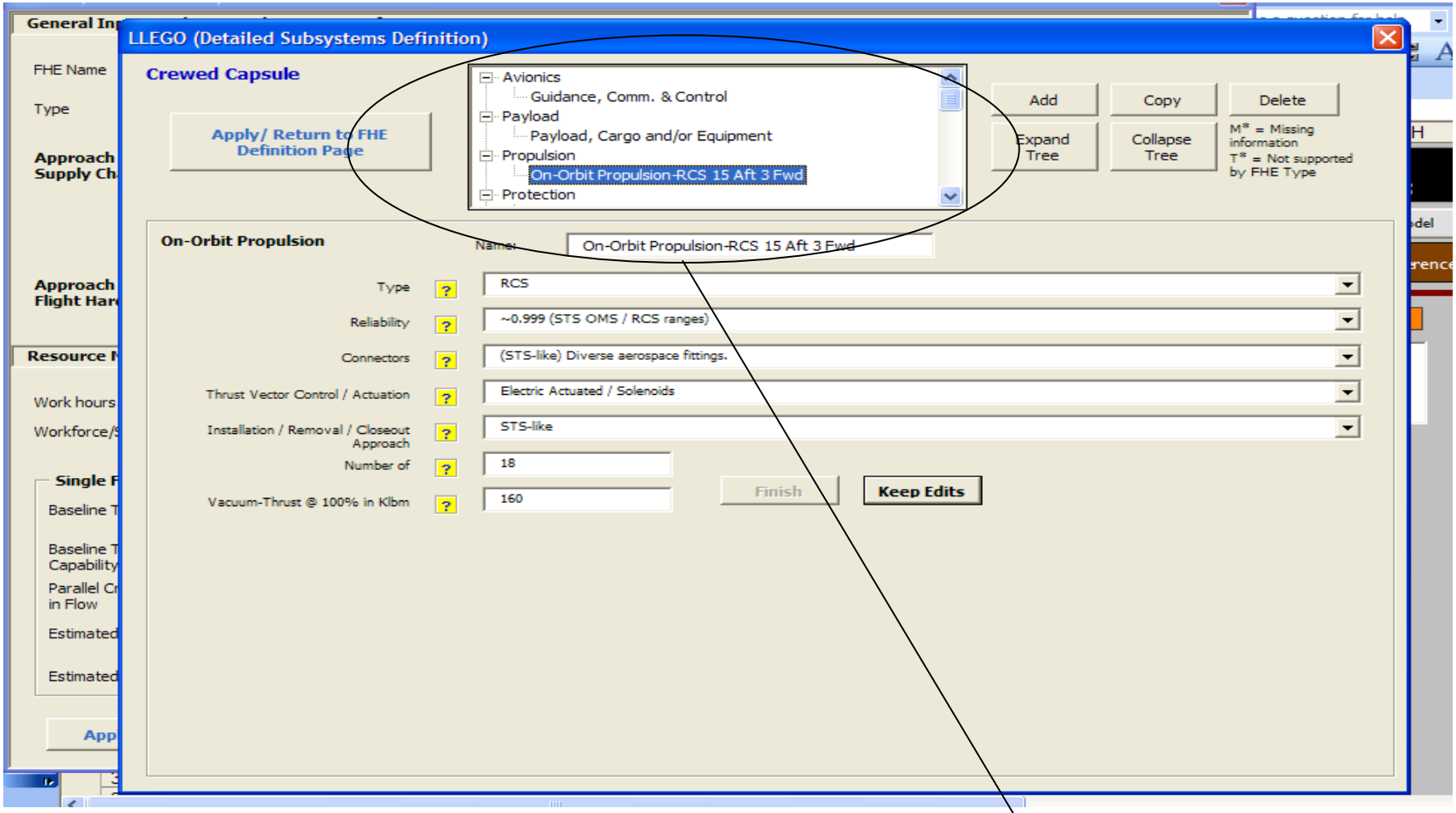
A new set of process, practices or technology can be applied to either the standalone contractor, the integration contractor (GOE) or the government (CMO etc).

Demo-Importing a Baseline File including Sub-Systems Definition



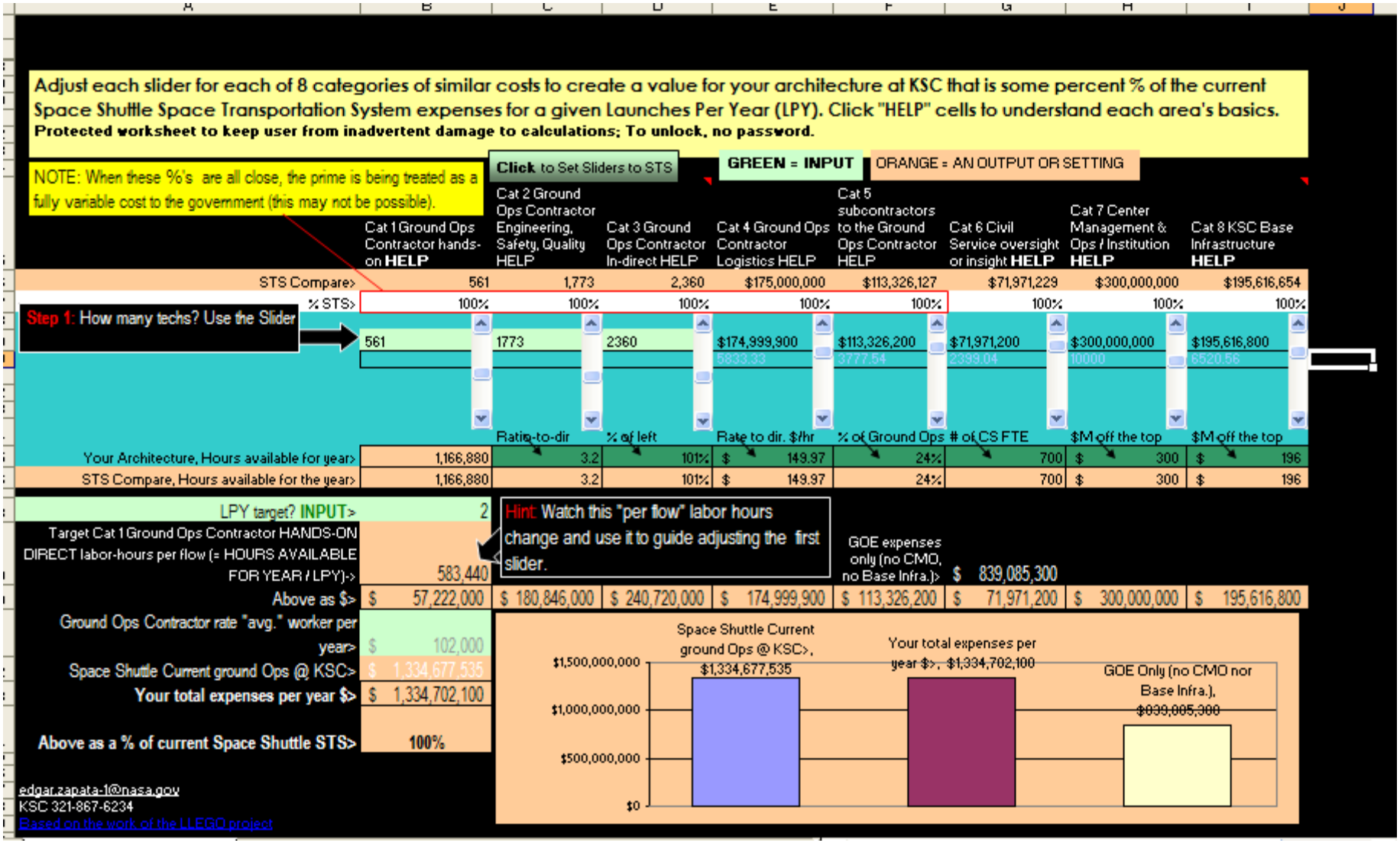
The prior were all relatively simple, direct calculation modes, going to more complex modes, from sub-systems descriptive definition…Flight Hardware Element Model…Import, browse for C:drive, Blue Frog, LLEGO, LLEGO Files…"CapsuleB.fhe"…

Demo-More Sophisticated Sub-system Definition & Drivers being Chosen… Design for Ops…



Straight forward, traditional sub-system breakdown structure

Also Available for Distribution-Slider Tool



Also Available for Distribution-SRM Balancer Tool

SYSTEM REQUIREMENTS INPUTS New (file not saved)

New Open Save Save As Full Analysis Quick Analysis Help About Exit

Architecture Elements Add Copy Delete

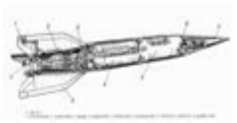
AE - 1

Name AE - 1

Type None Specified

Ratio of Parallel Work (Duration:Work) 1:1

Number of Subsystems 1



Move Up Move Down

Update Architecture Element and Subsystems

Architecture Parameters

Abort System Reliability 0.90000000000000

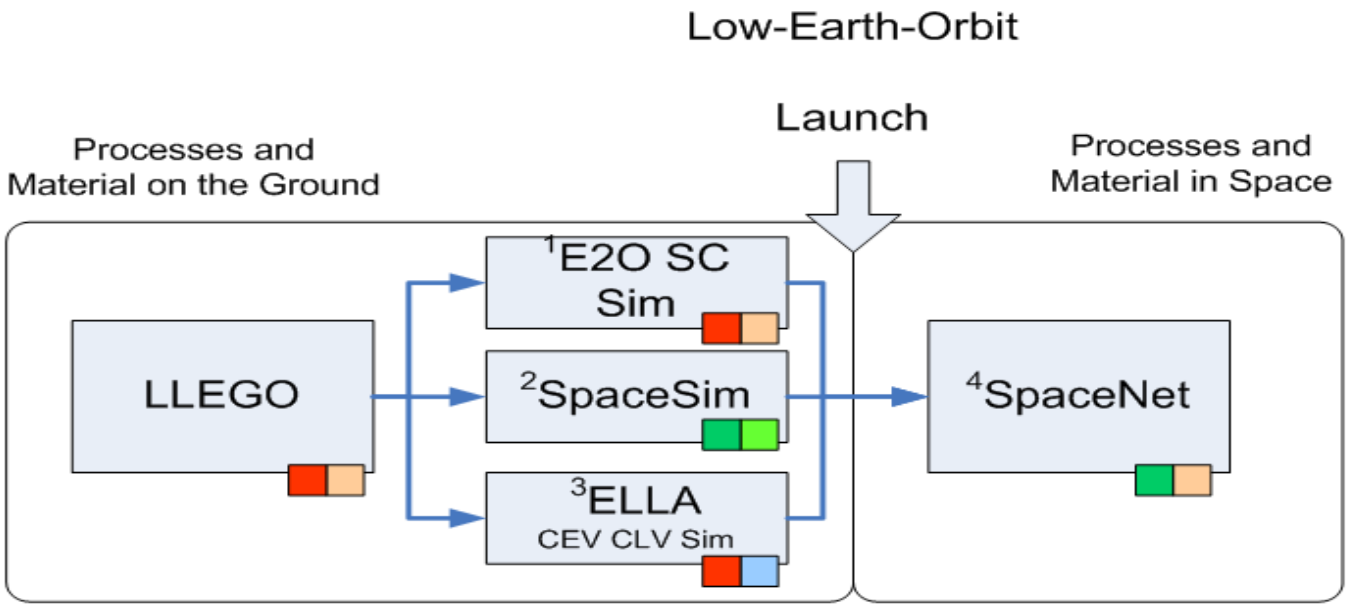
Work Hours in a Week 40 hours (1 Shift)

Target Maximum Processing Duration (in weeks) 20

Update Architecture Parameters

Design Constraints & Requirements							Resultant R & M Effects			
Name	Effect (0-2)"	Avg. Reliability per Comp	Basic Functional System # Comps	# of Critical Functions	Redundancy Level	Repair time	I # Comps	Expected Failures	Expected Repair Time	Reliability
>Subsystem - 1 - 1	2	0.99	100	10	1	100	0	1.01	101.01	0.9043821

Relation to Other Projects
Options, Recent Projects

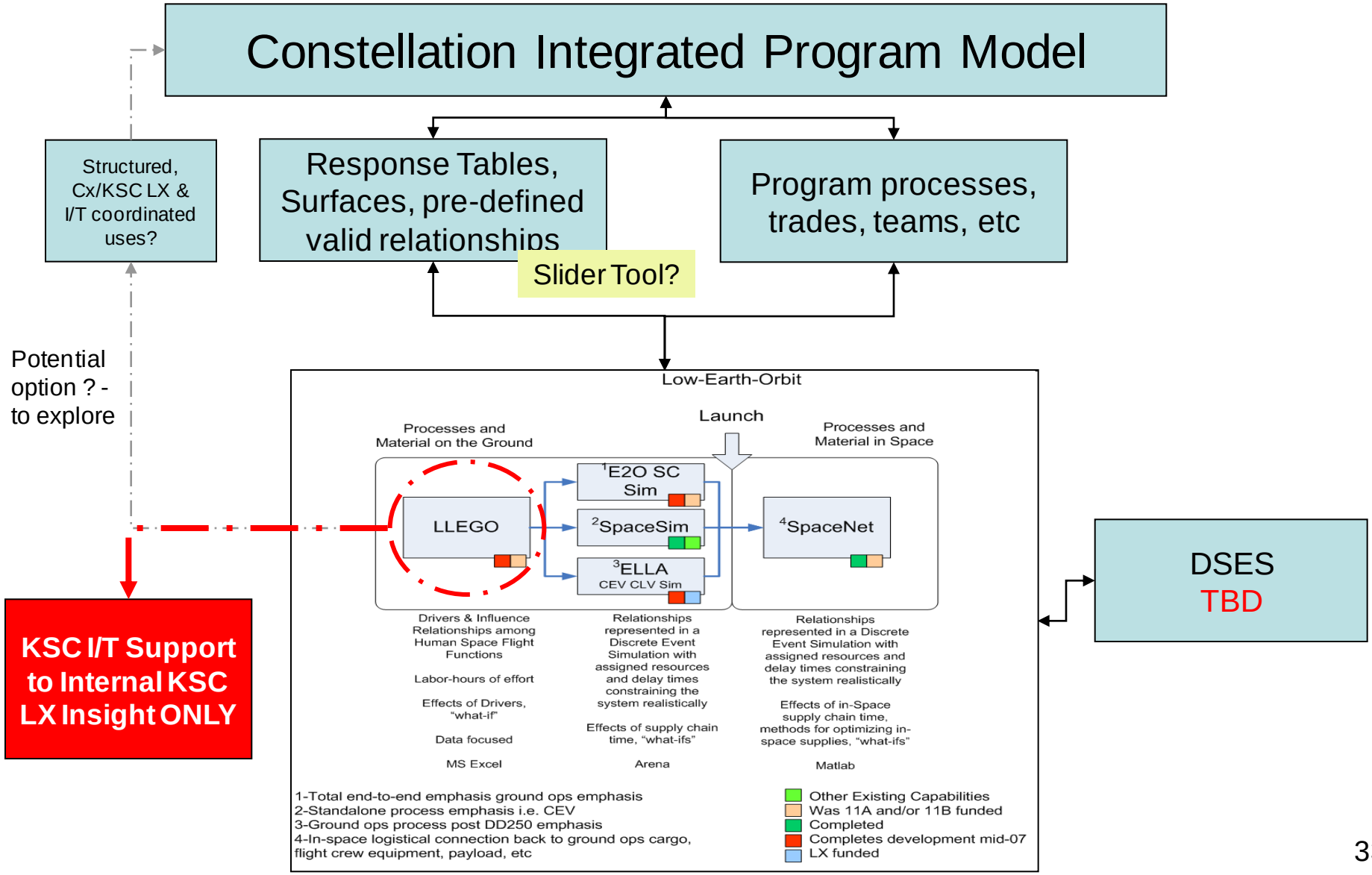


Drivers & Influence Relationships among Human Space Flight Functions	Relationships represented in a Discrete Event Simulation with assigned resources and delay times constraining the system realistically	Relationships represented in a Discrete Event Simulation with assigned resources and delay times constraining the system realistically
Labor-hours of effort	Effects of supply chain time, "what-ifs"	Effects of in-Space supply chain time, methods for optimizing in-space supplies, "what-ifs"
Effects of Drivers, "what-if"		
Data focused		
MS Excel	Arena	Matlab

1-Total end-to-end emphasis ground ops emphasis
2-Standalone process emphasis i.e. CEV
3-Ground ops process post DD250 emphasis
4-In-space logistical connection back to ground ops cargo, flight crew equipment, payload, etc

- Other Existing Capabilities
- Was 11A and/or 11B funded
- Completed
- Completes development mid-07
- LX funded

Relation to Other Projects
Option, the Cx IPM



Closing

- **Distribution of LLEGO will likely be in 2 versions**
  - SBU Government Use Only
  - Non-Government, stripped of some trace data and comparative analyzers
  - LLEGO configuration info will be kept on the web to assist in keeping users synched
- **Analysis case definition, sensitivity studies and exploring scenarios is underway**
- **User manual wrapping up, additional help screens being added**
- **Here to support!**

Backup Provided Separately